

HOMER

SEWARD

Kustaninow Park

Icefield

Harding

Resurrection Bay

Aialik Bay

Northwestern Fjord

McCarty Fjord

Gulf of Alaska

Ecological Overview of Kenai Fjords National Park

By Page Spencer and Gail V. Irvine

The major drivers of Kenai Fjords ecosystems are tectonics and climate. In this overview, we describe how these forces have contributed to the shaping of the lands and ecosystems of Kenai Fjords.

Physically, the park is comprised of several distinct components, set within a broader ecophysical framework that includes the Kenai Peninsula and coastal marine waters and islands. Squeezed between the Gulf of Alaska and the Kenai Mountains, the coastal zone of the park is a narrow band of exposed headlands and deep fjords. The Harding Icefield caps the Kenai Mountains above the fjords with ice estimated to be 3,000 feet (1,000 m) thick (Figure 1). Although not included in the National Park Service jurisdiction, the park is ecologically linked to the offshore marine ecosystem, and the embedded offshore islands, most of which are part of the Alaska Maritime National Wildlife Refuge, managed by the U.S. Fish and Wildlife Service.

Plate Tectonics

Kenai Fjords National Park rides the exposed edge of the North American plate where the Pacific plate is “diving” beneath the North American plate. As crustal plates have slowly moved northward, they have brought parcels of land (terrane) that were accreted onto the margin of the North American plate in a series of deformed arcuate ridges and basins. These features form the present day Kenai and Chugach Mountains and the Cook Inlet basin. Upper Jurassic and Cretaceous-aged rocks stretch from Kenai Fjords near Gore Point through the Chugach Mountains as far east as Glacier Bay (Plafker *et al.* 1994).

The park’s position on the junction of two crustal plates makes it prone to earthquakes of moderate frequency and intensity, with resulting ocean floor landslides and terrestrial uplift and subsidence. The beautiful circular bays of the Aialik, Harris, and McCarty Peninsulas are drowned cirques of the Chugach Mountains, which were partially submerged by tectonic subsidence

during the Holocene (Hamilton and Nelson 1989) (Figure 2). A dozen earthquakes of magnitude 6.0 or greater have occurred in the region during the past century (Haeusser and Plafker 1995). The last great earthquake in southcentral Alaska, before 1964, occurred approximately 800 years ago (Mann and Crowell 1996).

The epicenter of the 1964 Great Alaska Earthquake was 95 miles (150 km) northeast of the town of Seward, and 100-150 miles (150-250 km) from the coast of Kenai Fjords (see article by J. Freymueller, this issue). Land deformation following the earthquake was distributed along a “hinge” line of zero vertical motion that runs offshore of Kenai Fjords. Subsidence occurred to the northwest and uplift to the southeast of this line. Additional coastal erosion was caused by underwater landslides in the fine-grained silts and clays deposited by glacial rivers at the head of Resurrection Bay. Similar landslides (and tsunamis) may have occurred in Beauty Bay and North Arm of the McCarty Fjord at the western



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Figure 2. Aerial view of the drowned cirques of the Harris Peninsula.

(Left) Figure 1. Landsat TM image of Kenai Fjords region. August 8 and July 26, 2000.

Composited and enhanced by Michael Fleming, USGS. Design by Dave Allen, USFS.

Warming and cooling cycles have resulted in multiple glacial advances and retreats. Unlike many glacial terrains where cooling trends reduce summer melting, bringing on glacial advances, the Kenai Fjords glaciers move forward when warmer weather brings moisture-laden storms to the coast. Air is rapidly forced over the abrupt mountains and drops copious snowfall onto the Harding Icefield.

end of the park. However, most of the fjords have very steep bedrock walls or tidewater glaciers at their heads and lack sediment buildups. Saltwater intrusion and tidal flooding following subsidence have converted freshwater wetlands and spruce forest bands throughout the fjords to tidal marshes and “ghost forests” (Figure 3). Much of Prince William Sound was located on the southeast of the hinge line and experienced uplift, with Montague Island experiencing an extreme elevation rise of 38 feet (12 m) (Plafker 1969).

Climate and Glaciers

In addition to the important influence of plate tectonics, climate has been a recurrent, powerful theme and driver of many changes in Kenai Fjords and its environs.



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Figure 3. “Ghost forest”: Sitka spruce killed by saltwater intrusion onto land in Beauty Bay that subsided in the 1964 earthquake.

Most obvious, perhaps, is the effect of climate on glaciation. Basic alteration of the weather leads to changes in temperature and precipitation, which affect snow pack formation and glacial movements. It also affects the freshwater contribution into the coastal marine system, which coupled with wind, are primary forcers of the dynamics of the Alaska Coastal Current that flows along the coast.

Pleistocene and Holocene glaciations have shaped the land and ecological processes of the coastline. Warming and cooling cycles have resulted in multiple glacial advances and retreats. Unlike many glacial terrains where cooling trends reduce summer melting, bringing on glacial advances, the Kenai Fjords glaciers move forward when warmer weather brings

moisture-laden storms to the coast. Air is rapidly forced over the abrupt mountains and drops copious snowfall onto the Harding Icefield.

There have been at least four major glacial advances in southcentral Alaska during the late Pleistocene and early Holocene eras (25,000 to 9,000 years ago) (Reger and Pinney 1996). These glaciations swept 50-100 miles (80-160 km) beyond the current coastline to the edge of the continental shelf (Molnia 1986). Ice that is more than a mile (1.6 km) thick completely covered the Kenai Mountains. Moving ice over a mile deep exerts powerful forces on the terrain beneath it. The ice has carved off all soft and loose material, leaving steep, polished bedrock walls and deep submarine valleys all along the Kenai coast.

More recent glaciations, although impressive in their impacts on the landscape, are mere whimpers in the scheme of glacial cycles. The glaciers reached their last maximum late in the nineteenth century and are currently undergoing a fairly dramatic retreat (Wiles and Calkin 1994). Nearly 40 outlet glaciers flow off the Harding Icefield, seven of which terminate as tide-water glaciers in Aialik, Northwestern, and McCarty Fjords. Approximately 100 years ago, these fjords were filled with glaciers that rested on terminal moraines miles seaward from their current termini (see article by Valentine et al., this issue). McCarty Glacier has retreated 14.5 miles (23 km), and Northwestern and its associated glaciers have retreated more than 9 miles (15 km) since 1909 (Rice 1987).

The Harding Icefield is the largest of four permanent icefields in the Kenai Mountains, covering approximately 700 square miles (1,800 km²). This flat cap of largely stagnant ice blankets the mountains above 1,650 feet (500 m) (Wiles 1992). Scattered nunataks (Figure 4) rise above the icefield to 6,500 feet (2,000 m) on Truuli Peak, the highest point on the Kenai Peninsula. The icefield receives three to four times the precipitation that falls at sea level. Rice (1987) cored the Harding Icefield above Exit Glacier and measured nearly 20 feet (6.3 m) of accumulated snow, equivalent to 11.3 feet (3.5 m) of water for snow-year 1984-85. As the outflow glaciers of the Harding Icefield rapidly retreat, the overall area of the icefield also reduces. However, the icefield seems to be accumulating ice and thickening in its upper reaches.

Climate

Current icefield conditions reflect modern climate. At present, Kenai Fjords has a typical maritime climate, with cool, rainy summers and snowy, storm-driven winters. The occasional calm sunny day is a treat to be savored. Steep mountains rising from sea level to more than 5,000 feet (1,530 m) force moisture-laden storms to rise, where cooling temperatures and reduced moisture-holding capacity cause the clouds to drop massive amounts of snow onto the Harding Icefield.

Lower elevations are the recipients of heavy rains and misty days. Ferocious storms rake the outer coasts, especially the headland cliffs and outer fjords exposed to prevailing southeast storms. North Pacific atmospheric low pressure systems curl counterclockwise right into the Kenai Fjords coast. Rainfall is heaviest in Aialik Bay, ranging from 45-80 inches (100-200 cm) during the summer months, decreasing by 50% along the coast to McCarty Fjord at the west end of the park (NPS 1999). Aialik



Photograph taken by Bruce Griffin

Figure 4. Bedrock nunataks on the skyline are surrounded by the Harding Icefield.

Bay frequently receives three to four inches (7.5-10 cm) of rainfall in one day, and on August 20, 1993 received a memorable 10.55 inches (27 cm).

Rainfall and glacial melt feed freshwater streams, which on the coast tend to be short and very steep. Waterfalls abound, including an 800-foot (250 m) waterfall above the North Arm of Nuka Bay. Recent deglaciations have opened up new streams and lakes, which are being colonized by salmon. The most recent example of this is Delectable Lake on the east side of McCarty Fjord, which became ice-free within the past 40

years. Although the stream is steep, fast, and very rocky, sockeye, coho, and pink salmon have ascended it to spawn in the lake (York and Milner 1999). Glacial streams, formed of meltwater from grounded and hanging glaciers, also tend to be short, but have a lower gradient than most of the clearwater streams. Sediment loads tend to be higher at the upper ends of fjords, where glacial waters are slow to mix with main Gulf waters (Figure 1). Glaciers such as Bear, Dinglestadt, and Pederson have silty lakes at their terminal faces.

Freshwater discharges into the coastal

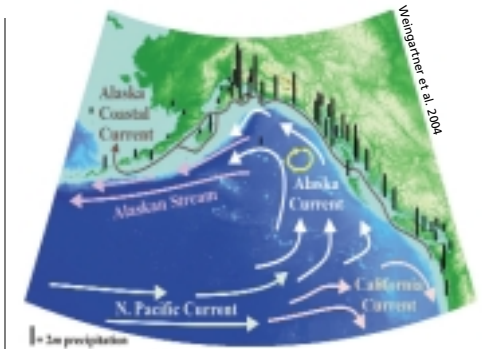


Figure 5. Regional circulation in the Gulf of Alaska with black bars indicating the mean annual precipitation. The Alaska Coastal Current is the dominant coastal current along the Kenai Fjords coast.



Photograph © Gail Irvine

Figure 6. Lush intertidal communities composed of marine algae and invertebrates on a rocky island in Kenai Fjords National Park. Note the pattern of vertical zonation expressed as bands of species.



Photograph © Page Spencer

Figure 7. Sea lions haul out on sloping rocks below a dense (and odiferous) kittiwake colony in Resurrection Bay.



Photograph © Page Spencer

Figure 8. Vegetation patterns from beach to bedrock, Bulldog Cove. Several lagoons have been formed as beaches are built in front of subsiding valleys. Sitka spruce forests grow around the lower slopes, rapidly giving way to alder, a narrow band of meadow and tundra, and bedrock, snow and ice.

marine waters, along with wind, drive the dynamics of the Alaska Coastal Current (Weingartner *et al.* 2004) (Figure 4). Although this strong current sweeps along the outer Kenai coast, its range is from British Columbia to the Bering Sea. Consequently, the Alaska Coastal Current functions as both a marine highway for migratory species and a conveyor belt passively transporting plankton, pollutants, and debris along its path. This current binds the offshore oceanic realm to the nearshore, influencing local productivity and climate, and in turn being profoundly affected by broader climate phenomena.

Climate and ocean dynamics in the North Pacific are linked in ways we are just beginning to discern. Variation in climate and biological productivity may occur on many time scales: daily, seasonal, annual, over a few years (e.g., El Niño), decadal (the Pacific Decadal Oscillation), centennial, or millennial (e.g., Mann *et al.* 1998). The wintertime location and intensity of the Aleutian Low pressure system in the North Pacific appears to be a primary driver of physical systems. Decadal shifts in these conditions are also translated biologically: in the magnitude of salmon runs, abundances of groundfish, shrimp, zooplankton, and fish larvae (Brodeur *et al.* 1996, Mantua *et al.* 1997, Anderson and Piatt 1999, Doyle *et al.* 2002).

Biological Systems

The nearshore marine environment of Kenai Fjords is an area of high productivity, which translates to rich marine ecosystems. In the pelagic portion of the nearshore, plant and animal plankton fuel the food

webs of higher consumers, such as fish, seabirds, and marine mammals. Some of this marine productivity is carried into watersheds by salmon, fertilizing terrestrial and freshwater systems with marine nutrients. Attached to the benthos, or bottom habitats, in the nearshore are dense communities of marine invertebrates and plants (Figure 6). These include the more obvious mussels, barnacles, starfish, sea urchins, popweed (*Fucus*), kelps (*Laminaria* and *Alaria*), and hosts of other species.

The nearshore pelagic realm supports many species of fish, including rockfishes, halibut, lingcod, pollock, and char. All five species of Pacific salmon migrate through offshore waters and spawn in Kenai Fjords streams. Forage fish, such as capelin and herring, and several species of shrimp abound. Commercial fishing for salmon and halibut occurs in the fjords.

The Alaska Coastal Current provides a migratory path for humpback, grey, minke, and fin whales in spring and fall. A few humpbacks linger and feed on planktonic crustaceans and small schooling fishes in such places as Resurrection Bay, Harris Bay, and McCarty Pass near Nuka Bay (Rice 1989). A pod of killer whales frequents outer Resurrection Bay. Dall's porpoises are frequently sighted at the mouths of the fjords, usually riding the bow wave of vessels. Harbor seals congregate at the upper ends of Aialik, Northwestern, and McCarty Fjords for pupping and molting on ice calved from tidewater glaciers. The largest sea lion rookeries are on exposed slanted rocks on the Pye and Chiswell Islands (Figure 7). Although much of the pupping and breeding activities take place in the

Maritime Refuge, sea lions use Kenai Fjords rocks as haulouts in smaller numbers. Major feeding and congregation areas for sea otters are the submerged moraines in Aialik, Northwestern, and McCarty fjords, and the sheltered coves and lagoons of Nuka Bay.

The cliffs of the exposed headlands and outer islands are teeming with seabird rookeries. The Chiswell and Pye Islands are nesting grounds for thousands of pelagic seabirds, including tufted and horned puffins, black-legged kittiwakes, murres, pigeon guillemots, and three species of cormorants. Smaller rookeries are found throughout the fjords, especially on the outer headlands and rocky islands inside the fjords. Marbled murrelets nest under glacial rocks (Rice and Spencer 1991) and on moss-draped branches of old Sitka spruce along the coast. Their haunting calls before dawn herald their return from a night's fishing at sea. Black oystercatchers scratch shallow nests into gravel beaches just above the tidelines and protect the nests vigorously from beach walkers. Glaucous-winged gulls are aggressively colonizing recently deglaciated islands in the fjords. Bald eagles nest along the coast, averaging 50 active nests per year. And crows cruise the beaches and wind currents with raucous calls.

Vegetation communities of the fjordlands reflect the harsh environment and Holocene glacial and tectonic history. Gravel beaches grade upward to the salt-tolerant community of beach ryegrass, beach pea, and beach greens, with scattered flowering forbs, such as iris and Jacob's ladder. Protected lagoons, like the backs of James and Beauty Bay, provide ample area for rich beds of goose tongue, a



Photograph © Bud Rice

Figure 9. A large mountain goat perches on a granitic rock near the sea. Goats seek shelter from winter storms in the stunted spruce at timberline and feed on dried grasses, forbs, and shrubs on wind-swept ridges.

favorite spring food for bears. Tufts of grasses and perennial forbs, some richly fertilized and aerated by nesting puffins, grow on exposed rocky cliffs.

Alder stands and Sitka spruce forests begin immediately above the storm tide

zone (Figure 8). Alder is a rapid invader in disturbed zones, following avalanche tracks from the alpine down to tideline. Scattered grasses and forbs find a foothold under the shrubs. Alder provides nitrogen for recently deglaciated soils, enriching the environment

for spruce invasion. Sitka spruce appears to move into de-glaciated terrain within 20 years of ice retreat (Rice and Spencer 1990). Recently developed Sitka spruce stands have uniform-aged trees with a thin moss ground cover, scattered grasses, and shrubs such as salmonberry and *Menziesia*. Older stands, growing through the last glacial maximum, have spruce and hemlock of varying ages, thick moss covering the ground and tree limbs, and alder, salmonberry, and Devil's club in openings. A Sitka spruce cut down in Palisade Lagoon in 1990 was more than 700 years old and seven feet (2.15 m) in diameter. Spruce forest refugia perched high in valleys above the ice limits provide seed sources miles up-valley of the glacial terminus forests. Nunataks within the ice-field are largely barren bedrock with prostrate tundra and lichen gardens found cupped in sheltered niches.

Terrestrial mammals have a scattered distribution along the coast. Many species had to survive the glacial era perched on the ice-free peninsulas and valley refugia. Others, such as bears, may have traveled over the Harding Icefield more recently. Both black and brown bears frequent the coast, feeding on tidal offerings, avalanche-borne carcasses, and spring greens until salmon start running each summer. Wolverines are frequently sighted at the heads of the fjords. River otters move along the coast, denning in the forests and fishing in the ocean and lagoons. Porcupines and red squirrels are moving up-fjord with the advancing spruce seedlings. Mountain goats use rocky cliffs along the coast (Figure 9). They are often sighted with their young kids at the ocean's edge, and spend winter

storms sheltered in spruce stands at timberline. Moose have made a recent appearance in Nuka Bay, where re-treating glaciers have opened a transit route through the valleys from Kachemak Bay.

Humans have lived along this coast for hundreds of years, moving in and out with the glacial movements and the associated resources (Crowell and Mann 1998). Aboriginal sites have been identified in Northwestern Lagoon, Yalik Bay, Aialik Bay, and McArthur Pass. People have been involved in successive waves of resource extraction along the coast: sea otter harvesting, gold mining, commercial fishing, scattered log-

ging, seal hunting (for bounty), and iceberg “mining” for sale to Japanese bars.

The creation of Kenai Fjords National Park in 1980 by the Alaska National Interest Lands Conservation Act provided the impetus for increased visitation to this wild and spectacular land. Currently, human visitation via day boat trips out of Seward is increasing rapidly. In 1989, two companies ran daily tours during the summer. Now three large companies with approximately 15 vessels make daily trips to Resurrection and Aialik Bays, and Northwestern Lagoon (Figure 11). Additionally, many smaller charters run fishing trips to Resurrection and Aialik

Bays. There has also been a rapid proliferation of kayakers who are taken to Aialik Bay or Northwestern Fjord in boats and dropped off for multi-day trips, or are flown from Homer to Nuka Bay. Four public use cabins were built by the NPS: two in Aialik Bay, one in McCarty Fjord, and one in the West Arm of Nuka Bay. These all receive extensive use, especially those in Aialik Bay. Impacts of beach campers on the nearshore meadows, oystercatchers, and black bears are being studied.

Other human activities and potential impacts are difficult to quantify. The 1989 Exxon Valdez oil spill and subsequent

cleanup activities severely impacted the coast of Kenai Fjords (Spencer 1990). Oil was still on beaches and driftwood in 1996 and documented at a residual oil-monitoring site in 1999 (Irvine et al. 2002, 2004). Oil is likely buried deep in gravel beaches and quiet backwater areas. The chance of another spill of similar magnitude is a function of the trajectories of circumstance and declining North Slope oil production. Oil-laden tankers travel offshore from the Cook Inlet oil field and the Valdez oil terminal. Additionally, the Alaska Coastal Current brings all kinds of marine debris to the outer beaches: drums, plastic of every description, and commercial fishing nets and floats.

Where Next...

And the really big unknown: global climate change. Warmer ocean currents may bring exotic species to our shores—already a green turtle gone astray was reported in Prince William Sound. Recent investigations using archeological midden materials suggest that climate has strong effects on the productivity patterns and strength of the Alaska Coastal Current (Irvine et al. 2003). Will global warming lead to a strong decrease in the flow rate of the Alaska Coastal Current? How would that affect nearshore productivity? Other studies suggest that global warming is increasing snow precipitation and building the Harding Icefield (Rice 1987, Wiles 1992). Will this lead to continued glacial retreat or advance? Whatever the future shifts in climate, they are sure to have profound effects on the dynamics of the interlocked landscapes and ecosystems in Kenai Fjords National Park.



Figure 10. A day boat loaded with eager passengers from Seward visits a sea lion haul out near Aialik Cape. Tour boats are required to maintain minimum distances from marine mammals.

REFERENCES

- Anderson, P.J. and J.F. Piatt. 1999.
Community reorganization in the Gulf of Alaska following ocean climate regime shift.
Marine Ecology Progress Series 189:117-123.
- Brodeur, R.D., B. Frost, S.R. Hare, R.C. Francis, and W.J. Ingraham, Jr. 1996. *Interannual variations in zooplankton biomass in the Gulf of Alaska and covariations with California Current zooplankton biomass.* CalCOFI Rept. 37: 81-99.
- Crowell, A.L. and D.H. Mann. 1998. *Archaeology and Coastal Dynamics of Kenai Fjords National Park, Alaska.* Research/Resources Management Report ARRCR/CRR-98/34. DOI-NPS. Anchorage, Alaska.
- Doyle, M.J., K.L. Mier, M.S. Busby, and R.D. Brodeur. 2002. *Regional variation in springtime ichthyoplankton assemblages in the northeast Pacific Ocean.* Progress in Oceanography 53 (2-4): 247-281.
- Hamilton, T.D. and S.W. Nelson. 1989.
Introduction, Guide to the Geology of the Resurrection Bay-Eastern Kenai Fjords Area.
Alaska Geological Society, Anchorage, Alaska. 1-4.
- Haeusser, P.J. and G. Plafker. 1995.
Earthquakes in Alaska. USGS Open file report 95-624.
1 map. (<http://quake.wr.usgs.gov/prepare/alaska/>).
- Irvine, G.V., S.J. Carpenter, D.H. Mann, and J.M. Schaaf. 2003.
A 6,300-year old window into the past: Retrospective analysis of nearshore marine communities based on analysis of archeological material and isotopic analysis. Draft Final Report, Project 03656, submitted to Exxon Valdez Oil Spill Trustee Council Restoration Program, Anchorage, Alaska.
- Irvine, G.V., D.H. Mann, and J.W. Short. 2002.
Residual oiling of armored beaches and mussel beds in the Gulf of Alaska. Final Report, Restoration Project 00459, submitted to the Exxon Valdez Oil Spill Trustee Council Restoration Program, Anchorage, Alaska.
- Irvine, G.V., D.H. Mann, and J.W. Short. 2004.
Persistence of ten-year old Exxon Valdez oil on Gulf of Alaska beaches: the importance of boulder armoring. Marine Pollution Bulletin. In press.
- Mann, D.H. and A.L. Crowell. 1996.
A large earthquake occurring 700 to 800 years ago in Aialik Bay, southern coastal Alaska.
Canadian Journal of Earth Sciences 33: 117-126.
- Mann, D., A.L. Crowell, T.D. Hamilton, and B.P. Finney. 1998.
Holocene geologic and climatic history around the Gulf of Alaska. Arctic Anthropology 35(1): 112-131.
- Mantua, N.J., S.R. Hare, Y. Zhang, J.M. Wallace, and R.C. Francis. 1997. *A Pacific interdecadal climate oscillation with impacts on salmon production.* Bulletin of the American Meteorological Society 78:1069-1079.
- Molnia, B.F. 1986.
Glacial History of the Northeastern Gulf of Alaska – A Synthesis. In Glaciation in Alaska, the Geologic Record, edited by T.D. Hamilton, K.M. Reed and R.M. Thorson. The Alaska Geological Society, Anchorage, Alaska. 219-235.
- National Park Service. 1999.
Weather Observation Data Set 1990-1998, Aialik and Nuka Bays, Kenai Fjords National Park. Digital files.
- Plafker, G. 1969.
Tectonics of the March 27, 1964, Alaska earthquake. U.S. Geological Survey Professional Paper 543-1.
- Plafker, G., J.C. Moore, and G.R. Winkler. 1994.
Geology of the southern Alaska margin. In The Geology of Alaska, edited by G. Plafker and H.C. Berg. The Geological Society of America. Boulder, CO. 153-204.
- Reger, R.D. and D.S. Pinney. 1996. *Late Wisconsin Glaciation of the Cook Inlet Region with Emphasis on the Kenai Lowland and Implications for Early Peopling.* In Adventures through Time: Readings in the Anthropology of Cook Inlet, Alaska, edited by N.Y. Davis. and W.E. Davis. Cook Inlet Historical Society. Anchorage, Alaska. 13-35.
- Rice, W.D. 1987. *Changes in the Harding Icefield, Kenai Peninsula, Alaska.* MS Professional Paper, University of Alaska, Fairbanks.
- Rice, W.D. 1989. *Sensitive Wildlife Habitat.* NPS files. 1:250,000. 1 map.
- Rice, W.D. and P. Spencer. 1990. *Tree cores of Sitka spruce along the temporal sequence of Northwestern Glacier.* Unpublished data collected in 1990.
- Rice, W.D. and P. Spencer. 1991. *Discovery of Marbled Murrelet Nest.* Alaska Bird Conference, Anchorage, Alaska.
- Spencer, P. 1990. *White Silk & Black Tar.* Bergamot Books, Minneapolis, Minnesota.
- Weingartner, T.J., S.L. Danielson, and T.C. Royer. 2004.
Freshwater variability and predictability in the Alaska Coastal Current. Deep Sea Research, Special Issue on the Northeast Pacific GLOBEC Program. In press.
- Wiles, G.C. 1992. *Holocene glacial fluctuations in the southern Kenai Mountains, Alaska.* Ph.D. dissertation, University of New York at Buffalo.
- Wiles, G.C. and P.E. Calkin. 1994. *Late Holocene, high resolution glacial chronologies and climate, Kenai Mountains, Alaska.* Geological Society of America Bulletin 106: 281-303.
- York, G. and A. Milner. 1999. *Colonization and Community Development of Salmonids and Benthic Macroinvertebrates in a New Stream within Kenai Fjords National Park, Alaska.* Final Report to the NPS, Cooperative Agreement No. CA 9700-2-9021. ENRI, University of Alaska. Anchorage, Alaska.